# THE INFLUENCE OF THE ILLUMINATION GEOMETRY AND LUMINANCE CONTRAST ON GLOSS PERCEPTION

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## ABSTRACT

Gloss is a main characteristic determining the appearance of objects. Physically, gloss results from directionally selective light scattering at the front surface of a material, with a preference towards the specular reflection direction. However, the sample illuminance and consequently the entire luminance distribution of the illumination scene around the sample could strongly influence gloss perception, especially for high glossy surfaces on which a reflected image becomes perceptible.

In this study, the influence of variations in illumination conditions and engendered luminance contrasts on gloss perception has been examined. A psychophysical experiment was conducted in a light booth, especially designed for this purpose. The final outcome of the study is a psychophysical scaling function, relating visual gloss to the luminance of both the reflected image and the surround.

Keywords: gloss perception, illumination, luminance contrasts

## INTRODUCTION

Gloss is generally related to the directionally selective reflectance properties of a surface [1], and the influence of front surface properties on gloss perception has been examined through different studies. Research results were reported on the interaction of surface gloss with texture [2], 3D shape [3-5] and colour [6].

An essential component in gloss formation that has received less attention is the illumination geometry. Obein examined the influence of a change in the direction of illumination (20° and 60° incidence angle) on gloss perception [7]. In a computer rendering experiment, Fleming measured the accuracy of observers to estimate surface reflectance properties (lightness and gloss) in complex realistic illumination conditions [8]. Finally, te Pas recently used photographs of objects under collimated and diffuse illumination conditions to investigate gloss perception [9]. However, the influence of real complex illumination and environment scenes on gloss evaluation of real objects has not been investigated yet.

## EXPERIMENTAL SETUP

A sample set was prepared including three flat glass samples of which the rear side was respectively painted white, grey and black. A light booth comprising two dimmable light sources was designed to perform visual assessments (see Figure 1).

A uniform rectangular light source is positioned 60 cm from the sample holder, with an incidence angle of 60° towards the sample normal (*specular light source*). Besides this generally adopted specular light source, an additional off-specular light source is introduced to mimic real-world illumination conditions. This luminaire is positioned perpendicular to the sample, again at a distance of 60 cm (*background light source*). A baffle between both light sources prevents mutual illumination.

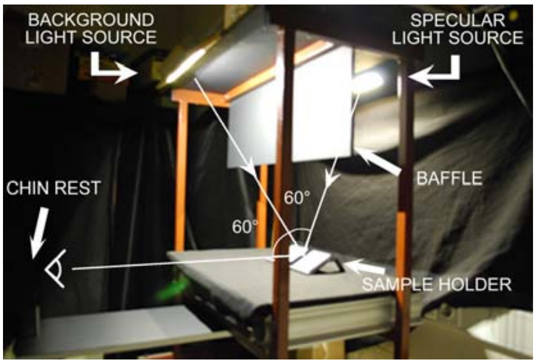


**Fig. 1: Side view of the test booth containing the specular and background light source.**

Samples are observed in the mirror reflection direction of the specular light source. The observer's head is fixed by a chin rest, which guarantees both a welldefined viewing direction and a viewing distance of 100 cm. Illumination and viewing distances are chosen such that the sample surface and the reflected image of the specular light source are both within the depth of focus of the eye.

65 different illumination conditions were generated by separate adjustment of the intensity of both light sources, through which also the luminance of both the reflected image and the adjacent off-specular surroundings were individually varied. Luminance measurements of the samples were performed from the observer's viewing position. The average luminance of the image of the specular light source, denoted by the image luminance $L_i$, and of both regions next to this image, denoted by the background luminance $L_b$, was calculated.

## VISUAL EXPERIMENTS

### Psychophysical experiments

Ten observers *O* rated the glossiness of the samples for the 65 illumination conditions *i*. A reference illumination condition on the white sample was presented at the beginning of each test, and observers were told to assign a reference value of 100 to this situation. All other test conditions were rated on a scale where zero represents no perceived gloss. Observers were not given an upper limit and were allowed to use any number they thought to be appropriate. Each observer performed the test in two different orders of presentation.

### Data analysis

Absolute magnitude estimation results were analysed using the method described by Luo [10] and Ji [11]. The geometric mean was computed to determine the mean observer's results. Results of all individual observers were normalized against the geometric mean function with the equation:

$$\log \hat{S}_i = a \log S_{i,O} + b , \qquad (1)$$

where $\hat{S}_i$ is the calculated geometric mean value for illumination condition *i*, and $S_{i,O}$ the raw gloss estimation value of observer *O* for the same illumination condition. Coefficients *a* and *b* were calculated for each individual observer using the least-square fitting method.

The coefficient of variation *CV* was used to measure the observers' agreement. CV is defined as

$$CV = \frac{100}{\bar{y}} \sqrt{\frac{\sum_{i=1}^{65} (x_i - y_i)^2}{65}} , \qquad (2)$$

with *x* and *y* two sets of estimation data for the 65 illumination conditions *i*, and $\bar{y}$ the mean value of dataset *y*.

## RESULTS

Normalized observer results $S_{i,O,norm}$ are plotted against the geometric mean data $\hat{S}_i$ in Figure 2. The average values of *CV*, for each individual observer tested against the geometric mean function, are gathered in Table 1. The average *CV* value of all observers is 6.6%. This value is inferior to the CV value calculated by Luo when rating colourfulness [10]. Yet, it is slightly larger than the values found by Ji in his experiments on gloss [11].

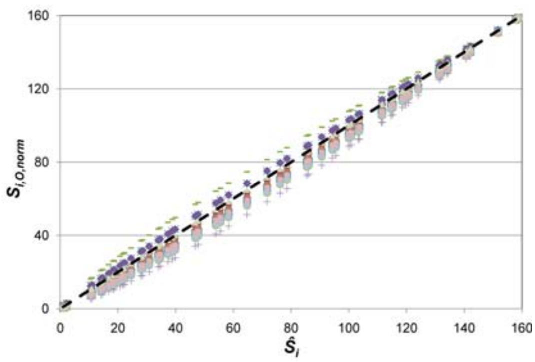


**Fig. 2: Normalized observer results $S_{i,O,norm}$ plotted against the geometric mean data $\hat{S}_i$ .**

**Table 1: Average values of the Coefficient of Variation *CV* for all ten observers tested against the geometric mean function.**

| *Observer* | *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|---|
| *CV* (%) | 3.5 | 6.0 | 4.4 | 7.9 | 6.7 |
| *Observer* | *6* | *7* | *8* | *9* | *10* |
| *CV* (%) | 7.2 | 3.7 | 12.6 | 6.5 | 7.7 |

Finally, a correlation function was derived relating the geometric mean function to both the measured luminance $L_i$ and $L_b$. Various functional relationships were tested by use of least square fitting techniques. The goodness of fit was evaluated with the adjusted coefficient of determination $R^2$, and regression assumptions were checked with appropriate statistical tests. A remarkable good agreement was obtained with the function

$$VisualGloss = 0.28\sqrt[3]{L_i} - 0.21\sqrt[3]{L_b}\ . \quad (3)$$

The adjusted $R^2$ value is 0.96, and all regression assumptions are met. A graphic representation of this function, together with the geometric mean data, is presented in Figure 3.

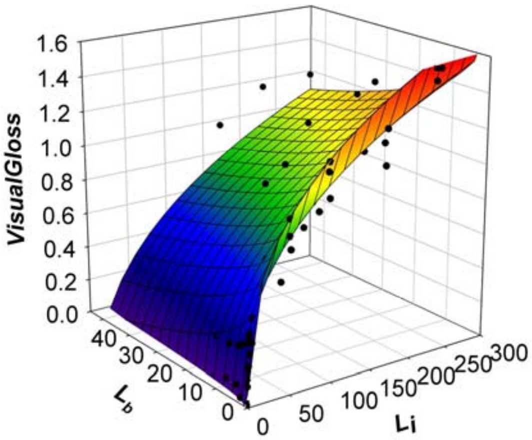


**Fig. 3: Both the geometric mean data and the derived *VisualGloss* function plotted against the measured luminance $L_i$ and $L_b$.**

## CONCLUSION

In this study, the influence of the illumination conditions on gloss perception was examined. Absolute magnitude estimation experiments were conducted, and a psychophysical function was deduced, relating visual gloss perception to the luminance of both the reflected image and the off-specular surround. It has become clear that not only the sample surface characteristics determine gloss perception: the illumination geometry could be an even important factor.

## REFERENCES

[1] International Lighting Vocabulary, CIE Publication 17.4, Vienna, ISBN 3 900 734 0 70 (1987).

[2] Y.-H. Ho, M. S. Landy, L. T. Maloney, Conjoint measurement of gloss and surface texture, *Psychological Science* 19 (2008) 196-204.

[3] R. W. Fleming, A. Torralba, E. H. Adelson, Specular reflection and the perception of shape, *Journal of Vision* 4 (2004) 798-820.

[4] J. F. Norman, J. T. Todd, G. A. Orban, Perception of three-dimensional shape from specular highlights, deformations of shading, and other types of visual information, *Psychological Science* 15 (2004) 565-570.

[5] P. Vangorp, J. Laurijssen, P. Dutré, The influence of shape on the perception of material reflectance, *ACM Trans. Graph.* 26 (2007) 77:1-77:9.

[6] B. Xiao and D. H. Brainard, Surface gloss and color perception of 3D objects, *Visual Neuroscience* 25 (2008) 371-385.

[7] G. Obein, K. Knoblauch, F. Viénot, Difference scaling of gloss: Nonlinearity, binocularity, and constancy, *Journal of Vision* **4** (2004) 711-720.

[8] R. W. Fleming, R. O. Dror, E. H. Adelson, Real-world illumination and the perception of surface reflectance properties, *Journal of Vision* 3 (2003) 347-368.

[9] S. F. te Pas and S. C. Pont, Both illumination and the material of context objects influence perceived glossiness, *Perception* 38 *ECVP Abstract Supplement* (2009) 97.

[10] M. R. Luo, A. A. Clarke, P. A. Rhodes, A. Schappo, S. A. R. Scrivener, C. J. Tait, Quantifying colour appearance. Part I. LUTCHI colour appearance data, *Col. Res. Appl.* 16 (3) (1991) 166-180.

[11] W. Ji, M. R. Pointer, R. M. Luo, J. Dakin, Gloss as an aspect of the measurement of appearance, *J. Opt. Soc. Am. A* 23 (1) (2006) 22-33.

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